Appendix C

Current Information on Mine Waste Treatment Technologies

Appendix C provides a compilation of various mine waste treatment technologies currently in use or actively being developed. The technologies presented are organized into the following groups: Waste Treatment Technologies and Waste Containment and/or Prevention Technologies. Information including the technology/method, vendors (if applicable), applicable sites, and a description of the technology are provided for each mine waste treatment presented.

Appendix C

Current Information on Mine Waste Treatment Technologies[1]

Technology/ Method	Vendor(s)	Applicable Sites	Description of Technology
Waste Treatment Technologies			
Alkalinity-Producing Systems (APS)	Not Available	The Douglas Highwall AML site, Tucker County, WV	Alkalinity-Producing Systems (APS) combine the use of an anoxic limestone drain (ALD) and anaerobic compost wetlands. Ponded water about 3 to 6 feet in depth overlies an 18-inch layer of organic material, usually compost, which is over an 18- to 24-inch layer of limestone. Acid water is ponded over the materials and the head created by the column of water forces the water through the organic material **to filter out or precipitate ferric iron and to consume oxygen through organic matter decomposition**. Alkalinity may be increased by microbial sulfate and iron reduction. The acid water, now low in dissolved oxygen and ferric iron after passing through the organic substrate, is then directed down into the layer of limestone under the organic matter or through pipes into a conventional ALD.

[1] Some technologies noted in this table may not have been commercially applied.

Technology/ Method	Vendor(s)	Applicable Sites	Description of Technology
Aluminator® Passive Treatment System	Damariscotta, Inc. Clarion, PA	Metro Site, PA; Casselman River Watershed in Somerset County, PA	Aluminator® is a patent-pending adaptation of a limestone drain in which **aluminum hydroxide will accumulate for recovery, and the aluminum-recovery and processing system**. The Aluminator® was developed by Damariscotta, Inc., a small company located in Clarion, PA. It is being used in Phase II of the Metro site project, performed in conjunction with PA Department of Environmental Protection, U.S. Office of Surface Mining, Southern Alleghenies Conservancy, Somerset Conservation District, Western Pennsylvania Watershed Protection Program and local land-owners and partners.

Technology/ Method	Vendor(s)	Applicable Sites	Description of Technology
Anoxic Limestone Drains (ALD)	Mackenzie Burnett, Burnett Engineering, Inc. 816 Traver Trail Glenwood Springs, CO 81601 (970) 928-8504	Two unnamed mine sites in Tennessee; Fabius Coal Preparation Plant, AL (non-NPL)	A limestone drain is a simple treatment method which involves the burial of limestone in air-tight trenches that **intercept acidic discharge water**. Keeping carbon dioxide within the drain can enhance limestone dissolution and alkalinity production. Furthermore, keeping oxygen out of contact with the discharge water minimizes the potential for oxidation of dissolved iron and the consequent precipitation of solid iron hydroxide [$Fe(OH)_3$], which could armor the limestone and clog the drains.
Bauxsol	Virotec Administration Building 50b Pinewood Drive Sanctuary Drive, 4212 Queensland Australia (07) 5530 8014	Gilt Edge Mine, SD	Bauxsol is a complex mix of Fe- and Al-oxyhydroxides and complex alumino-hydroxy-carbonates. Consisting of predominantly fine particles (with a high surface area to volume ratio and a high charge to mass ratio), it **allows difficult and toxic metals to seek out their least soluble (least mobile) compound**. Bauxsol generally sequesters over 99.99 percent of all heavy metals from soils and water including acid, arsenic, cyanide, and toxic metal combinations. Its acid neutralization capacity is high, due to the abundance of amorphous and finely crystalline mineral phases that form weak bases. When fine-grained Bauxsol is added to metals-laden wastewater or soil, reagents quickly drop out of any solution and settle within 48 hours to form a thin layer of sediment.

Technology/ Method	Vendor(s)	Applicable Sites	Description of Technology
Biological Treatment/ Constructed Wetlands	Not Available	Burleigh Tunnel wetland, CO (pilot-sized system); Asarco's West Fork Site, MO (non-NPL); Somerset Wetland, Somerset County, PA (non-NPL); Latrobe wetland, Westmoreland County, PA (non-NPL); Friendship Hill Wetland, Fayette County, PA (non-NPL)	Biological treatment consists of a series of shallow ponds planted with cattails. These constructed wetlands utilize soil- and water-borne microbes associated with wetland plants to **remove dissolved metals from mine drainage**. Initial design and construction costs may be significant. Unlike chemical treatment, however, wetlands are passive systems requiring little or no continuing maintenance. Wetlands are generally more effective in removing iron than manganese and the greatest utility of wetlands appears to be in the treatment of small flows of a few gallons per minute. This is a relatively new treatment technology with many specific mechanisms and maintenance requirements not yet fully understood. Seasonal variations in metal removal efficiency have been noted, with lesser amounts removed in cold weather.
Biological Reduction of Selenium (BSeR™)	MSE Technologies 200 Technology Way Butte, Montana 59702 Phone: 406-494-7367 Fax: 406-494-7230 www.mse-ta.com Applied Biosciences Corporation (AB) PO Box 520518 Salt Lake City, UT 84152-0518 (800) 280-7852	Kennecott North, UT	This process uses specially developed biofilms that contain specific proprietary microorganisms in anaerobic solids bed reactors to reduce selenium (in the form of selenite and selenate) to elemental selenium. The end product is a fine precipitate of elemental selenium that is removed from the bioreactor with backflushing. The process has a **97% rate of selenium reduction**.

Technology/ Method	Vendor(s)	Applicable Sites	Description of Technology
	(801) 468-1897 info@bioprocess.com www.bioprocess.com		
Catalyzed Cementation of Selenium	MSE Technologies 200 Technology Way Butte, Montana 59702 Phone: 406-494-7367 Fax: 406-494-7230 www.mse-ta.com	Kennecott North, UT	Catalyzed cementation **removes heavy metals from solution** by cementation on an iron surface. The process is optimized by adding catalysts that increase selenium removal efficiency. Feed water is fed through a series of static mixers where pH is lowered before entering the elemental iron reactor. The reactor is a specialized tank designed to fluidize iron particles. The iron particles carried out are trapped in a small, cone-bottom tank and pumped back to the reactor for reuse. The processed feed water exiting the small, cone-bottom tank is routed to an 80-gallon reactor where the pH is raised again with a lime slurry and an oxidizer is added which completes the required reaction.
Ceramic Microfiltration	BASX Systems LLC Fort Collins, CO	Black Hawk and Central City, CO	This treatment system is designed for the **removal of heavy metals** from an acid mine drainage system. It utilizes ceramic microfiltration to remove the precipitated solids. The first step in treatment is the conversion of heavy metals into a form that can be precipitated. If the metal finishing operation contains hexavalent chromium, it must first be reduced to trivalent chromium. The next step is to add the remaining metal-containing wastewater. The wastewater will then proceed through a hydroxide precipitation step, which consists of adding sodium hydroxide. The pH will be adjusted to between 8.5 and 9.5 in a two-stage pH adjust system. The wastewater is then transferred to the concentration tank. At this point the wastewater will be pumped through the cross flow ceramic membrane. The absolute pore size of the membrane is 0.2 microns. Therefore, the only metals that will remain in the filtered water will be dissolved metals.

Technology/ Method	Vendor(s)	Applicable Sites	Description of Technology
Colloid Polishing Filter Method (CPFM)	The Filter Flow Technology, Inc. (FFT)	DOE Rocky Flats Plant, CO	The CPFM system is designed to **remove a wide range of ionic, colloidal, and complex non-tritium radionuclides and heavy metals** from water. Pollutants are removed from water predominantly by sorption or chemical complexing down to parts per million (ppm) or parts per billion (ppb) levels. The CPFM technology can be used as a stand alone unit to treat low-total suspended solids (TSS) water or in a treatment train, downstream from other technologies such as soil washing, or conventional wastewater treatment using flocculation and solids removal. In general, low levels of radionuclides and heavy metals are the most suitable for treatment by the CPFM system.
Conventional neutralization	Not Available	Not Available	This is a commonly used treatment method whereby acid mine drainage is pumped to a central location to be mixed with an alkaline chemical, such as lime or sodium hydroxide, and mechanically aerated in large basins. The pH is raised to a level between 9 and 11, which **causes most metals to hydrolyze and precipitate as a sludge**. Some metals, such as iron, must be oxidized to be precipitated as a stable compound, which is why aeration is required. The resultant sludge-water mixture then flows to a clarifier or a series of settling ponds. This process is generally considered to be simple, but inefficient and expensive.
EcoBond™ Acid Rock Drainage (ARD)	MT^2, LLC 2801 Youngfield Street, Suite 300 Golden, Colorado 80401 303-205-7935 303-205-7925 Fax info@metalstt.com	Gilt Edge Mine, SD; Clear Creek (Gregory Gulch OU), CO	EcoBond™ is a treatment that effectively **inhibits the oxidation of pyrite, curtailing the pyrite oxidation cycle before it begins**. EcoBond™ forms a chemical chain that binds with metal ions forming insoluble metal complexes, thus reducing bioavailability. It produces a reaction that proceeds at ambient temperatures and does not produce secondary waste streams or gases. EcoBond™ can be applied in-situ or ex-situ in a wet or dry form. It stabilizes metals within 24 to 48 hours of application, reduces the solubility of treated metals by as much as 10 to 1,000 times, and increases the volume of waste by only one to five percent.

Technology/ Method	Vendor(s)	Applicable Sites	Description of Technology
In-Line Aeration and Neutralization System (ILS)	US Bureau of Mines, US DOE	Not Available	The In-Line Aeration and Neutralization System (ILS) utilizes a jet pump or eductor to **entrain the air and alkaline chemical** by Venturi action and a static mixer. Sodium hydroxide or sodium carbonate is added to the AMD with aeration to create flocculation. The flocculant is directed through a static mixer, to a clarifier and then to settling ponds. The overflow of the settling ponds is then treated with Biobeads or Zeolites for ion exchange. The ILS has no moving parts and operates by water pressure generated by the existing mine-water pumps. It is a pipeline version of a conventional water treatment system, and is more efficient and less expensive to install, operate, and maintain.

Technology/ Method	Vendor(s)	Applicable Sites	Description of Technology
Inundation	Not Available	Eagle Mine, CO	Constructing impoundments to inundate isolated areas of surface mines has been used to **minimize or eliminate AMD**. Saturation of acid-producing spoils may not always improve pH, but there is usually some reduction in metal concentrations. However, the drainage often has a less deleterious effect on downstream water quality than that from unreclaimed areas. The creation of an impoundment in the final cut of a surface mine forms recreation areas, aids in recharging the water table in the local area, and can eliminate or greatly reduce the amount of pollution from AMD and silt. The impoundment can also be designed so the body of water will completely flood any deep mine workings or auger mining holes, thereby limiting pyrite oxidation. Inundation is only suggested where a water table may be re-established to cover the materials (such as below drainage deep mines) and has not been recommended for surface mined lands or above drainage deep mines in the mountainous Appalachian region. Complete inundation has been successful in other areas where acid-producing materials are submerged in lakes or other permanent impoundments. Inundation of an underground mine can be an effective method of decreasing AMD by depriving pyrite of oxygen. In addition, if overlying rocks contain carbonate minerals, flooding can provide additional alkalinity by increasing the volume of alkaline strata in contact with mine water. On the other hand, if the mine walls contain readily soluble oxidation products of sulfides, inundation will cause a temporary increase in acid concentrations that should decline over time. If the water table fluctuates and the mine does not remain inundated, oxidation of pyrite can cause continued water pollution and the temporary increase in acid concentrations becomes an increase that does not decline over time.

Technology/ Method	Vendor(s)	Applicable Sites	Description of Technology
Ionic State Modification Process (ISM)	HPT Research, Inc. 13010 Loma Rica Drive Grass Valley, CA 95945 530-274-7631	Iron Mountain Mine, CA; Leviathan Mine, CA	This process relies upon technology that **provides the means of altering the chemical and physical properties of metal contaminants within aqueous solutions**. It begins with the injection of a proprietary chemical additive into the raw influent. The waste stream then enters the Ionic State Modification (ISM) Reactor. The ISM Reactor contains electrodes surrounded by patented magnets capable of producing strong, focused magnetic fields. When a current is applied to the electrodes, the combined forces have the ability of modifying the ionic composition of targeted metal ions within the waste stream, **causing these contaminant materials to either be reduced or oxidized to a chemical state that allows them to precipitate using conventional precipitation chemistry**.
Limestone Pond	Not Available	Not Available	Limestone ponds are a passive treatment idea in which a pond is constructed on the upwelling of an AMD seep or underground water discharge point. Limestone is placed in the bottom of the pond and the water flows upward through the limestone. Based on the topography of the area and the geometry of the discharge zone, the water can be from 1 to 3 meters (m) deep, containing 0.3 to 1 m of limestone immediately overlying the seep. The pond is sized and designed to retain the water for 1 or 2 days for limestone dissolution, and to keep the seep and limestone under water. Like anoxic limestone drains (ALDs), this system is **recommended for low dissolved oxygen (DO) water containing no Fe3+ and Al3+**. However, the advantage of this system is that the operator can observe if limestone coating is occurring because the system is not buried. If coating occurs, the limestone in the pond can be periodically disturbed with a backhoe to either uncover the limestone from precipitates or to knock or scrape off the precipitates. If the limestone is exhausted by dissolution and acid neutralization, then more limestone can be added to the pond over the seep. Three limestone ponds have been installed but no information is available on their treatment.

Technology/ Method	Vendor(s)	Applicable Sites	Description of Technology
Nanofiltration membrane technology	Hydranautics 401 Jones Road Oceanside, CA 92054 760-901-2500 www.membranes.com Dow Chemical www.dow.com	Kennecott South, UT	Nanofiltration is a form of filtration that uses a semi-permeable membrane. The pores are typically much larger than those used in Reverse Osmosis (RO) - close to one nanometer diameter - thus it is not as fine a filtration process as RO. Typical nanofiltration membranes **pass a higher percentage of monovalent salt ions than divalent and trivalent ions**. Most nanofiltration membrane polymers carry formal charges which exclude higher valence ions more than monovalents from passing through the membrane with the solvent water.
Open Limestone Channels/	Not Available	Not Available	Open limestone channels are the simplest treatment systems where **limestone fragments are added directly to the stream channel semiannually or less frequently**. Slow dissolution rates, armoring, burial, and transport of limestone from the channel during high flow are concerns.
Passive Bioreactor	Knight Piesold 1050 17th St., Suite 500 Denver, CO 80265-0500 303-629-8788	West Fork Mine (Non-NPL), MO	The passive bioreactor at West Fork Mine is a gravity-flow system covering about five acres. The system is composed of a settling basin for **solids removal**; two anaerobic bioreactors that are arranged in parallel for **lead removal**; a rock filter polishing cell that **removes manganese, reduces biological oxygen demand (BOD), and sulfide and increases dissolved oxygen (DO)**; and an aeration pond **for final BOD and DO polishing**. The system is designed to treat influent having a pH of 8.0, and containing 0.4 - 0.6 mg/L of Pb and 0.18 mg/L of Zn. The design flow rate is 1,200 gallons/minute.

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Reverse Osmosis	GE Osmonics 800-848-1750 http://www.gewater.com/index.jsp Karcher www.karcher-vps.com	Kennecott South, UT	Reverse Osmosis (RO) is also known as hyperfiltration and is the finest form of filtration. It allows the **removal of particles as small as ions from a solution**. The process uses a semi-permeable membrane that allows purified fluid to pass through while rejecting the contaminants that remain. It utilizes pressure to reverse the flow of fluids towards a state of equilibrium, usually with a pump. At the Kennecott South site, RO is used with nanofiltration for pre-treatment to avoid RO membrane clogging, fouling, or damage. Fouling is a broad, generic term used to identify a multitude of time-dependent phenomena, which, singly or in combination, impact membrane performance.
Silica Micro Encapsulation	Klean Earth Environmental Company (KEECO) www.KEECO.com	Not Available	Silica Micro Encapsulation (SME) **encapsulates metals in an impervious microscopic silica matrix (essentially locks them up in very small sand-like particles) which prevents the metals from migrating or otherwise adversely affecting human health or the environment**. Its physical/chemical components include an initial exothermic reaction and pH adjustment followed by an electrokinetic reaction and metal hydroxyl formation which leads to silica encapsulation. SME is a very robust technology, demonstrated to work effectively on heavy metals (such as chromium, copper, lead, mercury and zinc), metalloids (such as arsenic), and radionuclides (such as uranium). It can be applied to wastewater, sediment, sludge, soil, mine tailings, and other complex media. In addition to the control of metals, SME chemicals have been shown to reduce dissolved solids (such as sulfates) and, through a high-energy oxidation process, to break down organics and hydrocarbons (i.e., gasoline and fuel oil).

Technology/ Method	Vendor(s)	Applicable Sites	Description of Technology
Waste Containment and/or Prevention Technologies			
Dewatering	Not Available	Falconbridge Fault Lake tailings site, WV	**Removing water (or dewatering) removes one of the principal reactants in pyrite oxidation, and should theoretically stop the production of AMD**. Without water to move reaction products from the surfaces of pyrite, no contamination of waters should occur. While this can be done in a laboratory setting, complete removal of water in nature is nearly impossible. However, reducing the amount of water contacting pyritic material and containing water that is in contact with acid-producing materials may reduce the impacts of AMD to off-site water bodies and streams. Removing water before it contacts pyritic material by pumping may also be done. Draining water away from pyritic materials as rapidly as possible may keep water from reacting and forming acid products. Chimney drains, highwall drains, french drains, and blanket or bottom drains are all reliable methods for moving water from spoil, refuse, and fills.
Grout Curtains and Walls	Not Available	Academic studies performed	Grouts can be used to separate acid-producing rock and groundwater. Injection of grout curtains may significantly **reduce the volume of groundwater moving through spoils and thereby greatly reduce the amount of AMD coming from a site**. In one sense, grouting to form curtains or walls is analogous to underground water diversion.
Revegetation	Not Available	Summitville Mine, CO; Big River Tailings Site, MO	Establishing vegetation is an important step in reclaiming AML. It helps **control soil erosion, encourages mine soil development, creates an aesthetically pleasing landscape, and contributes to productive post-mining land uses**. Two keys to successful revegetation of AML are the selection and placement of a mine soil that is well suited for the intended post-mining vegetation, and the selection of plant species that are well suited to both the mine soil properties and intended post-mining land use.
Soil Covers and	Not Available	Upshur Mining	Covers are constructed from natural or man-made materials that retard or divert the

Technology/ Method	Vendor(s)	Applicable Sites	Description of Technology
Plastic Liners		Complex, WV	movement of water and oxygen into areas containing acid-producing rock. Soil covers can achieve substantial **reductions in water flow through piles, but generally do not control AMD completely**. Plastic liners are rarely used in mining because covering large volumes of waste with a liner is usually too expensive. However, this method may be appropriate in settings where isolation of small pods of acid-producing material is possible.
Surface Diversion and Diversion Wells	Not Available	Rausch Creek, Dauphin County, PA (non-NPL); Lick Creek, Tioga County, PA (non-NPL)	Diverting surface water above a mined site to decrease the amount of water entering the mined area is highly recommended in acid-producing areas. This technique can **control water volume and direction and minimize the effects of AMD on receiving streams**. Surface diversion of runoff involves construction of drainage ditches to move surface water quickly off the site before infiltration or to limit its movement into the backfill. The diversion is accomplished either by ditching on the uphill side of surface mines or by providing new channels or impervious channels of existing surface streams to convey water across the disturbed area. Diversion wells utilize a strategy for alkaline loading that can be accomplished by diverting surface water into receptacles or beds of alkaline material (slag, crushed limestone, or other lime materials) to pick up alkalinity and allowing the alkaline water to flow into spoils or underground mine pools. This process needs periodic replenishment of limestone. Alkaline loading of water upgradient of mined areas or before it enters the backfill buffers the effects of subsequent contact with acid water.
Underground Mine Filling and Injection	Not Available	Longridge Mine, WV; Frazee Mine, MD; Mettiki mine, MD	Due to the miles of passages in underground mines where minerals have been removed, huge volumes of void space are available for mine pools to develop, and due to the local geological rock types, this water is often acidic. Filling the mine voids completely or creating barriers inside the mine to break up interconnected underground pools may be used to **control flow and improve drainage quality**. Materials to fill underground mines must be cheap and readily available, so waste products such as steel slags and fly ash are generally used in these situations.

Technology/ Method	Vendor(s)	Applicable Sites	Description of Technology
Underground Mine Sealing	Not Available	Not Available	Mine sealing can **minimize the AMD pollution associated with abandoned underground mines**. The primary factor affecting the selection, design and construction of underground mine seals is the anticipated hydraulic pressure that the seal will have to withstand when sealing is completed. A dry mine seal is a wall across a mine entrance where water does not drain from the entrance. A wet mine seal is a wall across a draining mine entrance that allows water flow through the seal but prevents air from entering the mine. Surface access seals (or dry seals) are installed in entries where little or no hydrostatic pressure will be exerted on the seals. The primary functions of these seals are to eliminate access to the mine and to decrease AMD production by limiting movement of air and water into the deep mine. Dry seals are typically constructed of concrete block, masonry, or concrete-fly ash mixtures, and are often backfilled from the front side of the seal. The lack of hydraulic head allows these seals to be simple in construction and low cost. Air trap seals (wet seals) are installed in mine entries where mine discharges flow from the mine. Wet seals almost always were constructed with concrete blocks and either holes were left or pipes were inserted into the block wall to allow drainage. Unfortunately, the long term effectiveness of these old wet seals was generally poor. Failures occur when debris and sediment clog the hole or pipe, thereby increasing the head of the impounded water and resulting in collapsing or leaking seals. Accessibility of the mine and seal location are important design considerations. Dry or wet seals placed at easily-reached portal entrances are considerably cheaper than portals with poor access.

Technology/ Method	Vendor(s)	Applicable Sites	Description of Technology
Arsenic Oxidation	Cooperative Research Centre for Waste Management and Pollution Control Limited (CRC); Australian Nuclear Science and Technology (ANSTO)	Valley Forge/Susie Mine; Helena, Montana	Arsenic Oxidation is an innovative technology in which **Arsenite is photochemically oxidized to create Arsenate**, which is then removed through an iron co-precipitation.
Mineral-Like Precipitation; Arsenic Removal	Dr. Larry Twidwell, Montana Tech Metallurgy Department	Not Available	The object of mineral-like precipitation is to **strip arsenic from solutions so as to produce mineral-like precipitated products that are stable enough to be stored in tailing pond environments**. A series of arsenate solids are crated and these solids are then identified by x-ray diffraction pattern analysis for separation.
Alumina Adsorption Arsenic Removal	ZENON Environmental Services, Inc.	Not Available	Alumina Adsorption is an innovative approach using **alumina with microfiltration that is most effective with arsenic**. Process water at a pH of 3 to 4 is pumped into slurried activated alumina. The alumina adsorbs Arsenate anions. Microfiltration then separates activated alumina from process water. Arsenic is then desorbed from aluminum using sodium hydroxide. Concentrated sodium arsenate brine is generated, recovered, processed, and converted for safer offsite disposal. Activated alumina regenerated and recovered for further Arsenic removal.
Ferrihydrite Adsorption	Not Available	Not Available	This technology is most effective with arsenic. The ferric ion must be present (Fe+3) in water and the Iron to Arsenic mole ratio should be greater than four (but the ion is not stable at a pH greater than 7). The ferric ion changes into a solid form. Dissolved arsenic is removed by lime neutralization in the presence of Fe+3. This forms an **arsenic bearing Ferric oxide (Ferrihydrite), which is then removed by solid/liquid separation using conventional settling and flocculation with pressure filtration**.

Technology/ Method	Vendor(s)	Applicable Sites	Description of Technology
Biological Cover	Not Available	Not Available	Used **whey and molasses based formulas to stimulate aerobic heterotrophs to consume oxygen instead of creation of pyrite oxidation and acid regeneration**. Whey was found to be more effective.
Cyanide Heap Biological Detoxification	MSE	Not Available	The goal of this method is to obtain significant reductions of weak acid dissociable cyanide. **Biological cyanide degradation is accomplished through stimulating indigenous bacterial through nutrient addition and optimizing growth conditions. Anaerobic, naturally occurring microorganisms reduce sulfides, sulfites, thiosalts, and hydrogen sulfide**. The biological treatment is non-toxic to the environment as bacteria return to natural levels when cyanide is depleted and detoxification ends.
Redox-Mediated Biotransformation	MWTP-QAPP	Gilt-Edge Mine	**In-situ biological treatment** designed to **remove the metals nitrate and sulfate** from mine waste water.
Bioremediation of Lakes	Not Available	Anchor Hill Pit	Create reducing conditions and stimulate bacteria growth activity to improve water quality and creates a long-term stable system. This is accomplished through the **addition of lime and proprietary organic material from Green World Science.**
Biocyanide removal	Pintail Systems, Aurora, Colorado	Echo Bay/McCoy Cove Mine	Provides a **natural, biological treatment process with non-toxic reactions, by-products, low application costs, and effective and quick treatment of cyanide**. Some bacteria can break down the bond between carbon and nitrogen, thereby assisting in the removal of heavy metals. As bacteria dies back to natural levels, the detoxification process completes itself.
Remote Monitoring Systems	MSE	Callilope Mine	**A wireless transmittal systems monitors the temperature, pH, flow, and water levels**. This facilitates the remote gathering of information in harsh environments. Solar power is employed to identify monitoring issues remotely while reducing labor costs. Web access to the data provided by this data transfer can be monitored world-wide.

Technology/ Method	Vendor(s)	Applicable Sites	Description of Technology
Gas-fed sulfate-reducing bacteria (SRB) treatment	Biomet Mining Corporation, Vancouver, British Columbia	Burkley Pitt Mine	This is a common method for the treatment of acid rock drainage. **Using technology which employs hydrogen gas from partial oxidation of natural gas and other fuels as an electron donor, sulfide is changed to sulfate.** This can also be sued for the reduction of copper sulfide, zinc sulfide, sodium hydrosulfide, and possible aluminum, iron, and manganese products. This technology is not ready for use.
DuPont Passivation Technology	University of Reno, Nevada	Not Available	The passivation process creates an inert layer on the sulfide phase by **contacting the sulfide with a basic permanganate solution to produce an inert manganese-iron oxide layer**. This layer prevents contact with atmospheric oxygen during weathering on the sulfide rock, thus preventing sulfuric acid generation.
EcoBond ARD	Macmin, Ltd., and Metals Treatment Technologies (MT^2)	Not Available	These technologies use a broad range of processes that **chemically transform metal contaminants into non-hazardous and less toxic new mineral compounds** thereby achieving environmental protection. EcoBond combines with metals to form extremely insoluble new minerals, which reduces bioavailability. The process uses a proprietary additive which is a nan-hazardous, chemical binder that reacts with heavy metals. Treating pyrite with EcoBond ARD inhibits the oxidation and hydrolysis of pyrite thus curtailing the pyrite oxidation cycle.
Krystal Bond	American Sensor Technologies	Not Available	Krystal Bond Technology is an advanced process in which **inorganic materials are molecularly diffused onto a metallic surface in the presence of certain gases**. A diffusion takes place at a sufficiently high temperature that is far below the melting point of the metal. As the process occurs, the bonding materials flows while assuring that the high yield strength properties of the metal are preserved. As the temperatures are reduced, the bonding material solidifies and secures the silicon strain gauge in position. This process provides a high electrical isolation with low leakage rates at 500VAC, making this technology ideal for process control applications. Operating at low strain levels, AST's specially grown and micro-machined silicon strain gauges yield a high output with low thermal errors.

Technology/ Method	Vendor(s)	Applicable Sites	Description of Technology
Active Water Treatment	Not Available	Not Available	Most active water treatment systems at metal mines rely on **standard alkali-addition procedures**. Lime, sodium hydroxide, and/or sodium carbonate are mixed into acid-metal water in treatments tanks and mechanically mixed for a fixed period. Next, there is an addition of some drinking water-approved flocculent to promote agglomeration of small precipitated particles, precipitate is filtered from the water, and some level of drying occurs. Precipitates are then stored on- or off-site.
Biopass system	Not Available	Not available	The Biopass system has been successfully used to **treat draindown fluids from abandoned cyanide heap leach pads containing cyanide and metal cyanide species in a natural to alkaline media**. These anaerobic systems sometimes require polishing to remove metals to the finer level required for discharge regulations, but alone do not remove manganese.
Permeable Reactive Barriers	Not Available	Not Available	Permeable Reactive Barriers **minimize oxygen infiltration by sequestering oxygen, typically in a nutrient laden fine organic material**. They provide organic "food" source to sulfate reducing bacteria to reduce sulfate to sulfide and precipitate metal sulfides. Metals or sulfate is sequestered in the barrier material by providing critical reactants along a groundwater flow path.